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Action of Sea-Water
Upon Cement

Civil Engineering
B. S.
1904

ACTION OF SEA-WATER UPON CEMENT

...BY...

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THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
PRESENTED JUNE, 1904

UNIVERSITY OF ILLINOIS

May 27, 1904 190

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

EDWIN BENJAMIN KARNOPP

ENTITLED ACTION OF SEA WATER UPON CEMENT

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering.

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HEAD OF DEPARTMENT OF Civil Engineering

Introduction.

The question of the stability of hydraulic cement when exposed to the action of sea-water has always been a matter of interest to engineers. The following references to actual work will show the importance of this subject.

In the construction of a dry-dock in Japan it was decided that the concrete should not be allowed to set in sea-water, and since the stability of the coffer-dam would not warrant the entire removal of the sea-water from the inside, fresh water from the city water works was allowed to flow in at the top and the sea-water was pumped out from the bottom until the

water in the coffer-dam was sufficiently diluted. The expense thought necessary in this case is shown by the fact that the coffer-dam originally contained 10,000 tons of sea-water and the interchange required 300,000 tons of fresh water.

At Key West is a sea-wall which is covered at high tide, and when the tide falls small puddles are left along the top of the wall. After a few years a knife blade could be easily sunk in to the concrete upon which the puddles had stood; while along the side of the wall where the sea-water did not long remain in contact with the surface, the concrete is hard. The conclusion is that the sea-water in the puddles on

the top of the wall had so acted upon the cement as to practically destroy the cement.

At St. Augustine a wall was built in the sea and an arch was built in the air, both at the same time and of the same material; also several experimental blocks were allowed to set in air for a week and were then placed in sea-water. After two years of exposure a hole was drilled into the arch which had been exposed in the air, and the cement was found hard and sound; but an examination of the sea-wall and the test blocks showed that the cement in both was very soft.

Purpose of this Thesis.

The above examples show that at least some hydraulic

cements are not durable when exposed to the action of sea-water; and therefore the writer determined to investigate the cause of this deterioration. Although it is probable that short-time laboratory experiments can not give conclusive evidence upon this question, the writer concluded to make some experiments to answer the following questions.

1. Will briquettes made with sea-water and stored in sea-water show any difference in tensile strength from those mixed with fresh water and stored in fresh water within four months?

2. Will a cement which gains its strength rapidly, indicating a high proportion of lime and alumina be acted upon more by sea-water than a cement that

gains its strength more slowly?

3. Will briquettes mixed with fresh water and stored in the same for three weeks and then stored in sea-water show higher tensile strength than those mixed with and stored in sea-water from the beginning?

4. Will sea-water act relatively less upon a neat cement than upon a porous sand mixture?

The Experiments.

The sea-water used in the above experiments was obtained by dissolving sea-salt in proper proportions. The following is the standard composition of sea-water.

Water	963.7
Sodium Chloride	28.0
Magnesium Chloride	3.7
" Sulphate	2.3
Calcium Sulphate	1.4
Potassium Chloride	0.8
Total	999.9

Five cements were used: two American portlands, Chicago AA and Atlas; one German portland, Alsen: two American naturals, Louisville Star and Akron. The sand was German standard sand which when used in the proportion of one cement to four of sand gave a very porous mass thus allowing the water to penetrate easily. That the water might have opportunity to penetrate the briquettes and then be replaced by a change of water, the pans were emptied every ten days or two weeks, the briquettes left to dry over night and the pans refilled next day. This was done always at the same time for all briquettes both fresh water and sea-water and neat and sand.

The proper degree of plasticity

for the neat cement mortar was determined by applying the Boulogne test.#

The 1:4 sand briquettes were mixed with ten per cent of water - in some cases fresh water and in others sea-water, as shown in Tables I and II. The mixing was thoroughly done and the briquettes were moulded by hand care being taken to secure uniformity. They were stored part of the time in fresh water and part of the time in sea-water - all as stated in Tables I and II. The purpose of the fresh-water tests was to establish a standard from which the action of the salts could be measured. The briquettes were broken at the ages indicated in the tables. The results in the tables for one

#Baker's Masonry Construction, 9th edition, p. 67.

day and for seven days are the means of three briquettes, the results for three weeks and two months are the averages of five briquettes and the results for four months are the means of four briquettes.

TABLE I.

TENSILE STRENGTH OF NEAT CEMENT BRIQUETTES.

POUNDS PER SQUARE INCH.

Name of Cement.	Kind of Water.		Age when broken.				
	Mixed	Stored	1 day	7 days.	3 wks.	2 mos	4 mos
CHICAGO AA PORTLAND.	Fresh.	Fresh.	100	553	755	744	615
	Fresh.	Fresh-3 wks then Sea.	—	—		757	624
	Sea.	Sea.	77	618	761	440	822
ATLAS PORTLAND.	Fresh.	Fresh.	59	552	716	702	630
	Fresh.	Fresh-3 wks. then Sea.	—	—		604	705
	Sea.	Sea.	71	603	659	206	407
ALSEN PORTLAND.	Fresh.	Fresh.	—	494	581	580	609
	Fresh.	Fresh-3 wks. then Sea.	—	—		645	324*
	Sea.	Sea.	—	486	641	599	614
AKRON NATURAL.	Fresh.	Fresh.	0	134	200	334	394
	Fresh.	Fresh-3 wks. then Sea.	—	—		324	389
	Sea.	Sea.	0	20	52	114	204
LOUISVILLE STAR NATURAL.	Fresh.	Fresh.	—	136	127	164	299
	Fresh.	Fresh-3 wks. then Sea.	—	—		165	351
	Sea.	Sea.	—	103	113	148	205

* The water in which these briquettes were immersed evaporated, and they stood in air for an unknown time.

TABLE II.

Tensile Strength of 1:4 Mortar Briquettes.

POUNDS PER SQUARE INCH.

Name of Cement.	Kind of Water.		Age when broken.				
	Mixed.	Stored.	1 day.	7 days.	3 wks.	2 mos.	4 mos.
CHICAGO AA PORTLAND.	Fresh.	Fresh.	0	90	122	141	162
	Fresh.	Fresh-3 wks then Sea.	—	—		163	187
	Sea.	Sea.	0	82	99	134	174
ATLAS PORTLAND.	Fresh.	Fresh.	0	75	115	142	170
	Fresh.	Fresh-3 wks. then Sea.	—	—		141	182
	Sea.	Sea.	0	61	106	146	184
ALSEN PORTLAND.	Fresh.	Fresh.	0	67	138	141	162
	Fresh.	Fresh-3 wks then Sea.	—	—		129	149
	Sea.	Sea.	0	106	126	147	152
LOUISVILLE STAR NATURAL.	Fresh.	Fresh.	0	0	30	59	83
	Fresh.	Fresh-3 wks then Sea.	—	—		59	100*
	Sea.	Sea.	0	0	32	76	149

*The water in which these briquettes were immersed evaporated, and they stood in air for an unknown time.

It remains to be seen whether the data in Tables I and II give any light as to the four questions stated on pages four and five.

1. Will briquettes made with sea-water and stored in sea-water show any difference in tensile strength from those mixed with fresh water and stored in fresh water, within four months?

This question is to be answered from a comparison of the first and last lines for each cement.

The results for neat Chicago AA are as follows:

	1 day.	7 days.	3 wks.	2 mos.	4 mos.
Fresh	100	553	755	744	615
Sea	77	618	761	440	822

The most remarkable fact about these numbers is the surprisingly low result for the sea-water briquettes at two months. The

writer can not understand the cause of this anomaly, as all of the sea-water briquettes were made at the same time and were stored in the same tray. A similar discrepancy, but of the opposite character, exists for the results at four months which is inexplicable. Omitting the values for the two months and the four months tests as being unreliable the remainder of the results do not differ sufficiently to warrant any definite conclusion.

The results for neat Atlas Portland are:

	1 day.	7 days.	3 wks.	2 mos.	4 mos.
Fresh	51	552	716	702	630
Sea	71	603	659	206	407

The noticeable feature of these results is the very low value for sea-water briquettes at two months and at four months.

The writer can not even make any hypothesis to account for these inconsistent results. They must be due to some undetected error in making or breaking the specimens; although the writer can not see how this is possible, since all of the fresh water were made at one time and all of the sea-water briquettes at another time.

The results for neat Alsen portland are:

	1 day.	7 days.	3 wks.	3 mos.	[illegible]
Fresh	—	415	521	530	607
Sea	—	486	[illegible]	511	617

The differences in this series are not sufficient to warrant any definite conclusions as to the effect of sea-water upon cement particularly in view of the unexplained discrepancies for the two preceding cements.

The results for briquettes of Akron natural cement made with

sea and with fresh water are as follows:

	1 day.	7 days.	3 wks.	2 mos.	4 mos.
Fresh	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sea	0	20	52	114	204

These results seem to indicate that sea-water materially weakens the cement at all ages. In a rough way the loss in strength decreases with the age of the briquette. The fact that the difference is so great at the earliest age and continually decreases probably indicates some error in the experiments.

For the Louisville Star natural the corresponding results are:

	1 day.	7 days.	3 wks.	2 mos.	4 mos.
Fresh	—	136	127	161	211
Sea	—	103	113	148	205

These show that at all ages the sea-water decreases the strength. The difference being greatest at the extreme ages probably indicates considerable error in

the experiments.

It is scarcely worth while to examine in detail the corresponding results in Table II, since a casual inspection shows that the apparent effect of sea-water is quite variable sometimes strengthening and sometimes weakening, and since the effect of sea-water is in no case continuous in one direction, these results seem to show that the experiments were not accurate enough to determine such an uncertain function.

2. The second question proposed for investigation is: "Will a cement which gains its strength rapidly, indicating a high proportion of lime and alumina be acted upon more by sea-water than a cement that gains its strength more slowly?" Since

in discussing question one it was concluded that the experiments were too inaccurate to show whether sea-water had any effect upon cement, it is clearly not possible from these experiments to show whether sea-water has different effects upon different Portlands or different natural cements.

3. The third question was: "Will briquettes mixed with fresh water and stored in the same for three weeks and then stored in sea-water show higher tensile strength than those mixed with and stored in sea-water from the beginning?" To answer this question requires a comparison in Tables I and II of the second and third lines for each of the several cements. Such a comparison shows

results erratic enough as to prove only that the experiments are too crude to detect such an effect — if one exists at all.

4. The fourth question is: "Will sea-water act relatively less upon a neat cement than upon a porous sand mixture?". The answer to this question involves a comparison of the differences between the results in the first and last lines of each cement in Table I with the like differences in Table II. Even a casual comparison shows that these differences are to erratic to warrant any conclusions.